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OPTIMIZING COST VERSUS TIME SHIPPING OF U.S. NAVY RETROGRADE MATERIEL

by

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March 2005

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The Naval Inventory Control Point (NAVICP) provides program and supply support for the weapons systems that keep our Naval forces mission ready. NAVICP conducts more than 380,000 repair actions annually to keep sufficient repair parts available or ready for issue to the fleet upon demand. These repair actions have totaled $3.08B in shipping and redistribution costs of Not Ready for Issue (NRFI) materiel. This thesis models the NAVICP shipping of unserviceable but repairable (retrograde) Navy materiel or Depot Level Repairables (DLRs). It develops an integer linear program to prescribe minimum cost shipment recommendations of DLRs from fleet to repair locations within the NAVICP and Defense Logistics Agency (DLA) distribution system subject to constraints on average shipping time (AveTime). NAVICP provided data on DLR shipments for one year from which we construct six representative DLRs, 3 of aviation and 3 of maritime cognizance. We find a cost and time savings can be achieved for all representative DLRs by avoiding the use of DLA as storage prior to induction for repair. In this study we compare shipping costs for each of the six DLRs when we constrain AveTime, from 2 to 8 days. We find 2-day constrained AveTime shipping, on average, costs 18 times that of 7-day AveTime shipping, twice that of 3-day shipping and a minimum of 5 times and a maximum of 11 times that of the costs of 4 through 6-day shipping.

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ABSTRACT

The Naval Inventory Control Point (NAVICP) provides program and supply support for the weapons systems that keep our Naval forces mission ready. NAVICP conducts more than 380,000 repair actions annually to keep sufficient repair parts available or ready for issue to the fleet upon demand. These repair actions have totaled $3.08B in shipping and redistribution costs of Not Ready for Issue (NRFI) materiel. This thesis models the NAVICP shipping of unserviceable but repairable (retrograde) Navy materiel or Depot Level Repairables (DLRs). It develops an integer linear program to prescribe minimum cost shipment recommendations of DLRs from fleet to repair locations within the NAVICP and Defense Logistics Agency (DLA) distribution system subject to constraints on average shipping time (AveTime). NAVICP provided data on DLR shipments for one year from which we construct six representative DLRs, 3 of aviation and 3 of maritime cognizance. We find a cost and time savings can be achieved for all representative DLRs by avoiding the use of DLA as storage prior to induction for repair. In this study we compare shipping costs for each of the six DLRs when we constrain AveTime, from 2 to 8 days. We find 2-day constrained AveTime shipping, on average, costs 18 times that of 7-day AveTime shipping, twice that of 3-day shipping and a minimum of 5 times and a maximum of 11 times that of the costs of 4 through 6-day shipping.

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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EXECUTIVE SUMMARY

The Navy intends to reduce costs associated with the shipping of unserviceable but repairable retrograde or Depot Level Repairable (DLR) materiel. This thesis models the Naval Inventory Control Point (NAVICP) distribution of unserviceable but repairable (retrograde) Navy materiel or DLRs. It develops an Integer Linear Program (ILP) to prescribe minimum cost shipment of DLRs from fleet to repair locations within NAVICP's distribution system subject to constraints on average time (AveTime).

The NAVICP provides program and supply support for the weapons systems that keep our Naval forces mission ready. Currently, the NAVICP manages more than 470,000 parts valued at $31B in its wholesale inventory. NAVICP Philadelphia (NAVICP-P) manages nearly 69,000 DLR line items that cost $1,566M to repair in 2003. NAVICP Mechanicsburg (NAVICP-M) manages 118,000 DLR line items that cost $209M to repair in 2003. NAVICP positions these items within a distribution network of 25 defense depots throughout the world operated by the Defense Logistics Agency (DLA). NAVICP conducts more than 380,000 repair actions annually to keep sufficient repair parts available or ready for issue to the fleet upon demand. In 2003, these repair actions have totaled $3.08B in shipping and redistribution costs of Not Ready for Issue (NRFI) materiel.

The retrograde distribution network is made up of five representative node types where 310 fleet units (Ships and Squadrons) are of node type one, 14 Advance Traceability and Control (ATAC) nodes in fleet concentration areas are of node type two, 2 ATAC hubs in Norfolk VA and San Diego CA are of node type three, 25 DLA Defense Distribution Depots (DDD) located worldwide are of node type four and more than 4,750 Designated Overhaul Points (DOP) for repair are of node type five.

NAVICP provided data on DLR shipments for one year. These data do not provide the location of DOPs; therefore, the author determines DOP locations manually to complete the distribution network. We construct six representative DLRs, 3 of aviation and 3 of maritime cognizance from these data.

We find a cost and time savings can be achieved for all representative DLRs by avoiding the use of DLA as storage prior to induction for repair. In this study we explore the tradeoff between cost and AveTime. When we constrain AveTime from 2 to 8 days, we compare shipping costs for each of the six DLRs. We find 2-day constrained AveTime shipping, on average, costs 18 times that of 7-day AveTime shipping, twice that of 3-day shipping and a minimum of 5 times and a maximum of 11 times that of the costs of 4 through 6-day shipping.

LIST OF ACRONYMS

AMC	Air Mobility Command
ATAC	Advanced Traceability and Control
DDD	Defense Distribution Depot
DLA	Defense Logistics Agency
DLR	Depot Level Repairable
DMISA	Defense Maintenance Intra Service Activity
DoD	Department of Defense
DODMDS	Department of Defense Materiel Distribution System
DOP	Designated Overhaul Point
FEDEX	Federal Express
FISC	Fleet Industrial Supply Center
ILP	Integer Linear Program
MRIL	Master Repairable Item Listing
NAVICP	Naval Inventory Control Point
NAVSUP	Naval Supply Systems Command
NIIN	Naval Item Identification Number
NRFI	Not Ready for Issue
RFI	Ready for Issue
UICP	Uniform Inventory Control Program

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ACKNOWLEDGMENTS

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I.   INTRODUCTION

The Naval Inventory Control Point (NAVICP) provides program and supply support for the weapons systems that keep U.S. Naval forces mission ready. Currently, the NAVICP manages more than 470,000 parts valued at $31 billion in its wholesale inventory. Nearly 190,000 of those parts are Depot Level Repairable (DLR) worth $23 billion [NAVICP, 2004a]. NAVICP stores these items using a distribution network of 25 Defense Distribution Depots (DDDs) throughout the world operated by the Defense Logistics Agency (DLA). NAVICP contracts for repairs of more than 380,000 parts annually to keep sufficient parts available or ready for issue (RFI) to the fleet upon demand. These repair actions have totaled $3.08B in shipping and redistribution costs [Smoak, 2004].

A.   THESIS OUTLINE

This thesis models the NAVICP distribution system of unserviceable but repairable Navy DLRs requiring more than 384,000 repair actions from June 2003 to May 2004. It develops an Integer Linear Program (ILP) to help recommend the best way to ship retrograde materiel.

The remaining parts of this chapter present an overview of the DLA and Navy inventory management system. Chapter II addresses related U.S. military and commercial studies of distribution systems. Chapter III introduces the ILP model. Chapter IV highlights the computational experience and includes characteristics of the test data set used for this analysis. Chapter V provides conclusions and recommendations.

B.   OVERVIEW OF NAVY RETROGRADE INVENTORY SYSTEM

This section contains basic information regarding the Naval Retrograde Inventory System. The system is made up of five entities: (1) the Naval Supply Systems Command (NAVSUP), (2) the NAVICP organization and (3) its Repairables Management program, (4) the 25 DLA DDDs that provide storage prior to induction into a Designated Overhaul

Point (DOP) for repair and (5) the Advanced Traceability and Control (ATAC) organization that streamlines the DLR returns to the repair cycle.

1.   Naval Supply Systems Command (NAVSUP)

The NAVSUP is the Navy's hardware system command responsible for providing quality supplies and logistics services to naval forces around the world. NAVSUP provides weapons system support through the NAVICP and streamlined DLR processing through the ATAC program at its Fleet Industrial Supply Center (FISC) locations worldwide [NAVSUP, 2005]. Figure 1.1 shows the NAVSUP organization and its subordinate activities for repairables management.

Figure 1.1: Naval Supply System Command Team
The Naval Supply Systems Command Team including the Naval Inventory Control Point and the Fleet Industrial Supply Centers that manage the ATAC program. All six FISC locations listed above as well as the recently opened FISC Sigonella, Italy (not shown) serve as the entry point into the transportation pipeline for most DLR items. Figure from [NAVSUP 2005].

2.   Naval Inventory Control Point (NAVICP)

NAVICP, a subordinate NAVSUP activity, provides program and supply support for the weapons systems that keep our naval forces mission ready. NAVICP operates from two locations in Pennsylvania. The Mechanicsburg location provides supports for

maritime parts and Philadelphia provides support for aviation parts. A supply corps Rear Admiral serves as the commander of both locations [NAVICP, 2004b].

NAVICP, the Navy's only inventory control point, maintains worldwide control and visibility over Navy wholesale stock. NAVICP manages more than 470,000 line items valued at more than $31B. NAVICP Philadelphia (NAVICP-P) manages nearly 69,000 DLR line items that cost $1,566M to repair in 2003 [NAVICP, 2004b]. NAVICP Mechanicsburg (NAVICP-M) manages 118,000 DLR line items that cost $209M to repair in 2003 [Haynes, 2004].

3. Repairables Management (UICP Database)

Item managers at NAVICP decide when to buy, how much to buy and when to repair; as well as how much to repair, how much to hold on average, which units should be sent to disposal and when procurement actions should be cancelled. Currently, item managers use Item Manager Tool Kit for this function [NAVICP, 2004b]. Figure 1.2 shows the U.S. Navy Repairables Management Cycle.
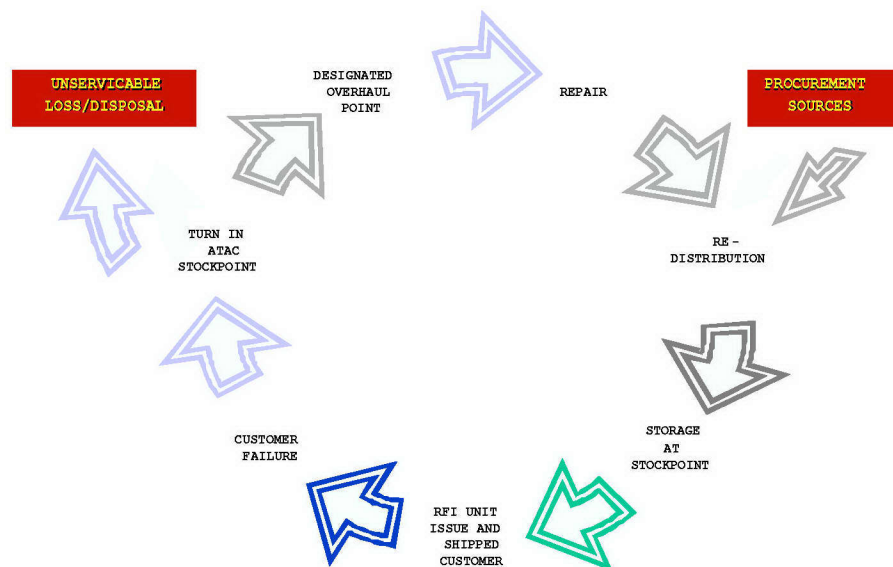

Figure 1.2: Navy Repairables Management Cycle
Navy repairables management inventory builds up through procurement and is distributed at stock points for storage prior to fleet issue. After failing, items are turned in to an ATAC for disposal or repair. If disposed the item goes to a DLA Defense Reutilization Marking Office location.

Item managers use the Uniform Inventory Control Program (UICP) in conjunction with Item Manager Tool Kit to determine repair workload levels. Workload forecasting and emergent requirements at DOPs serve as the driving factors for shipping and redistributions of retrograde materiel prior to repair. The UICP minimizes the annual variable cost equation composed of ordering costs, holding costs and shortage costs [NAVSUP, 1992]. "UICP is a highly automated, integrated system that, except for provisioning, provides automated applications software support for nearly the full range of NAVICP functions, including procurement and financial control" [NAVSUP, 1996].

4. Defense Logistics Agency (DLA)

The DDDs of DLA provide a single, unified materiel distribution system for the Department of Defense (DoD) under DLA management. The DDD located in New Cumberland, Pennsylvania is the lead center of the 25 DDD around the world. The DDDs store 4.0 million stock numbers in 327 million square feet of storage space and process over 23 million transactions annually. Clothing and textiles, electronics, industrial, general and construction supplies, subsistence, medical materiel and the military services' principle end items are among the commodities for which DLA is responsible. Responsibilities include receipt, storage, issue, packing, preservation, worldwide transportation, in transit visibility and redirecting enroute of all items placed under its accountability by the DLA and the military services. Figure 1.3 lists the names of the DDDs worldwide. [DLA, 2005]

Figure 1.3: Listing of 25 DLA's Distribution Depot locations

5.   Advance Traceability and Control (ATAC)

Developed in 1985, the ATAC system was implemented to minimize system design losses of failed DLRs or retrograde items and streamlines carcass return for these items [Ships Parts Control Center, 1994]. Specifically, ATAC hubs and nodes serve as the Navy centralized transportation system of Navy DLRs. ATAC provides tracking of retrograde DLRs returned to the supply system as an exchange for RFI materiel or as turn-ins for credit [NAVSUP, 1999].

ATAC is the Navy's first logistics pipeline to couple logistics and transportation into a single physical distribution system. DLRs are collected, identified, packed, and shipped from the Hub and satellite locations, known as nodes, where fleet activities are concentrated. [NAVSUP, 2005]

Prior to shipment, using the Master Repairable Identification List (MRIL), NAVICP determines whether to repair, stow, or dispose of the asset. DLRs to be repaired or stowed are then shipped to the appropriate site. DLRs designated for disposal are sent to the nearest Defense Reutilization & Marketing Office. Current ATAC policy mandates that NRFI DLR materiel slated for repair is first sent from the end user to an ATAC for processing and then forwarded directly to the DDD for storage at a facility adjacent to the

5

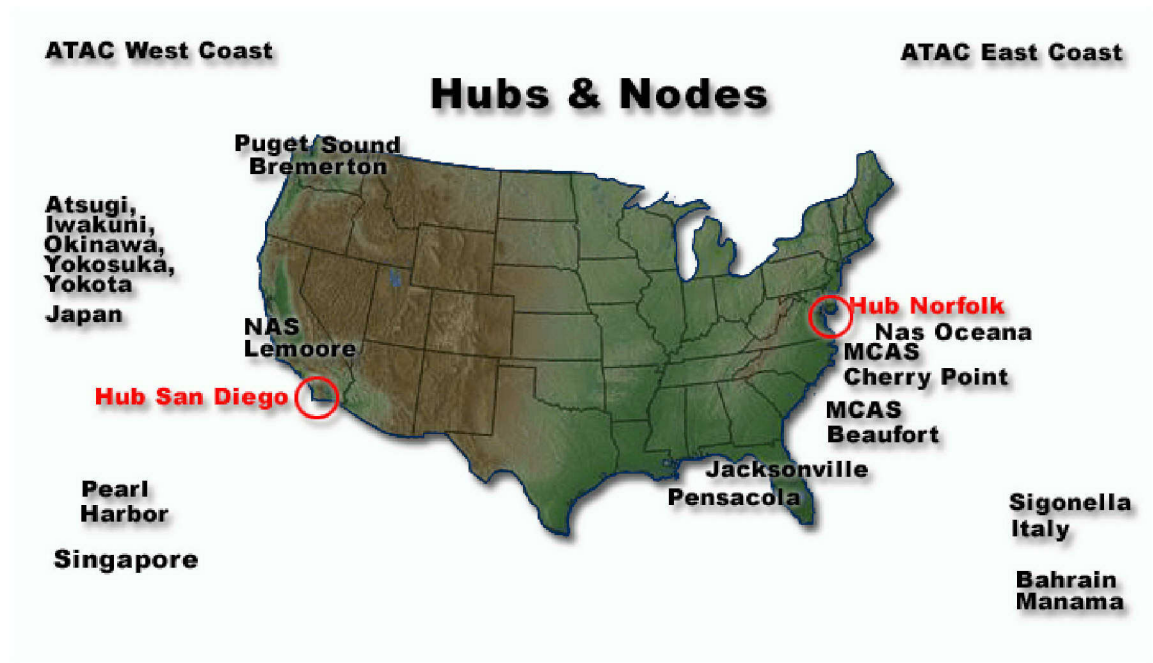DOP [Ships Parts Control Center, 1994]. Figure 1.4 shows the locations of ATAC hubs and nodes worldwide.

Figure 1.4 shows all 18 worldwide locations of the ATAC system.
The 16 field level nodes and 2 hubs (Norfolk, VA and San Diego CA) are transportation entry points of DLRs enroute to eventual repair at a DOP.

C.   CURRENT ISSUE

The Navy intends to reduce costs associated with the moving, repair and return of unserviceable but repairable retrograde or DLR materiel. This thesis shows how the Navy can minimize cost and time of shipping using the Navy's retrograde transportation network.

Current policy calls for the fleet units to initially send any retrograde to the Intermediate Level (I-Level) for repair. If the Intermediate Maintenance Activity cannot fix the DLR, the item is returned to the original activity (e.g., ship). NAVICP believes this is an unnecessary step in the repair and return cycle. Following the I-Level loop, the fleet unit then turns in its retrograde to the nearest ATAC location for packing, shipment and tracking. The 16 ATAC nodes worldwide and two ATAC hubs in Norfolk and San Diego forward the items to a DLA depot for storage or, if it is an aviation cognizance

6

item, they forward the item directly to a designated overhaul repair facility. Most maritime retrograde materiel remains at the nearest continental U.S. DDD owned by DLA. The materiel is then redistributed, preferably in mass, to the DOP when a repair requirement arises. Following D-Level maintenance, the item is deemed RFI and is then sent to its designated DDD for eventual issuance back to the fleet operating units. Figure 1.5 summarizes the flow of retrograde materiel.
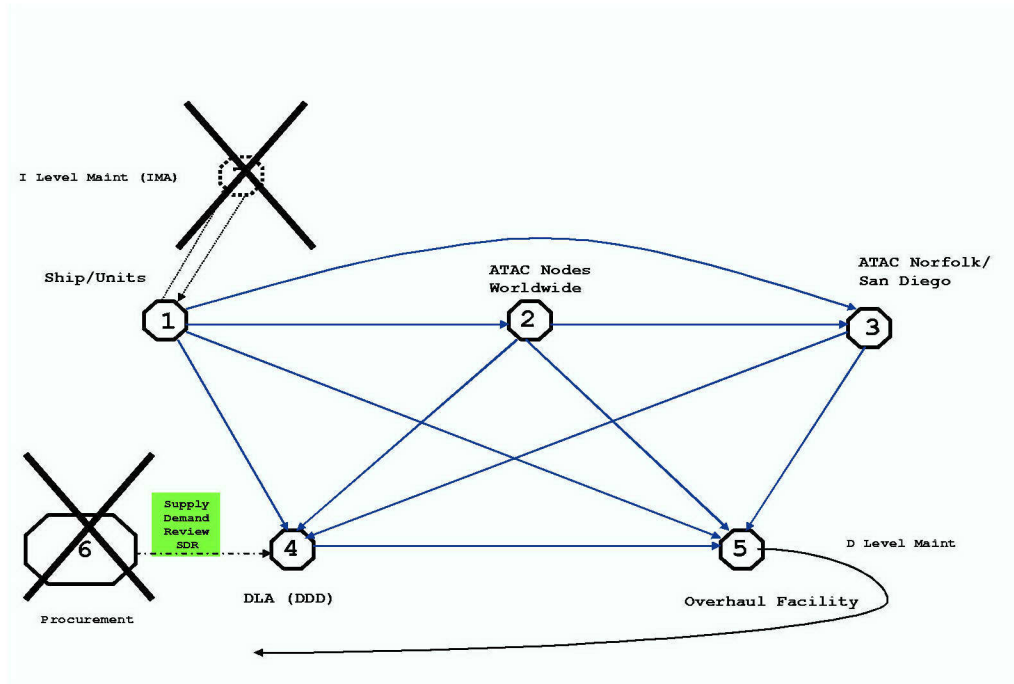

Figure 1.5: NAVICP retrograde distribution network for aviation and maritime materiel. Node One represents 310 ships and squadrons, node two represents one of the 16 ATAC field turn-in locations, node three represents the 2 fleet ATAC locations, node four 25 Defense Distribution Depots and node five represents the 4,726 Commercial, 21 DoD intra-service and 43 Navy (Organic) repair facilities. Not addressed in this thesis are procurement to make up for demand not met at repair facilities and I Level Maintenance (IMA) that NAVICP believes is an unnecessary step.

D.   OVERVIEW OF RETROGRADE NETWORK

This study conducts analysis on cost and time transshipment within the DLR materiel distribution network. Below is the identification and description of the DLR retrograde network analyzed in this thesis.

1. Ships/Naval Stations/End Users (Node Type 1)

Node type one consists of fleet level ships, squadrons and Naval and Marine Corps air stations.

2. ATAC Nodes (Node Type 2)

There are 14 fleet level ATAC nodes represented by node type two. ATAC nodes are located at fleet concentration areas, USN and USMC air stations or USAF airbases and serve as the initial receipt and transshipment points for NRFI DLR retrograde items enroute to its eventual repair location or DOP. Figure 1.6 shows DLRs being loaded at an ATAC for surface shipment using a DLA contracted truck for shipment to a DDD or a DOP.

Figure 1.6: DLR shipping from an ATAC to a DDD or a DOP.

3. ATAC Hubs (Node Type 3)

There are 2 ATAC hubs that make up node type three. ATAC Hub Norfolk, VA and ATAC Hub San Diego, CA. ATAC hubs serve as a transshipment point for DLRs prior to the items going into storage within the DDD system or before direct induction into for repair action at a DOP.

4.   DLA Depots (Node Type 4)

There are 25 DLA DDDs that make up the DLA storage and distribution system (Figure 1.7). Figure 1.8 shows a DDD storage location for NRFI DLRs awaiting induction into a repair cycle at a DOP.

Figure 1.7: Map Of DLA's Defense Distribution Depot Locations

Figure 1.8: Picture of NRFI DLRs at a DDD prior to shipment to a DOP for repair.

5.   Overhaul/Repair Facilities (Node Type 5)

NAVICP operates 3 types of overhaul repair facilities. Commercial, Defense Intra-service (DMISA) and Organic or Navy owned. DMISA facilities are U.S. military repair facilities that operate under the four military services. For example, the T-56 turboprop engine used on the C-130 Hercules aircraft is flown by the Navy, Marine Corps and Air Force aviation units. Consequently Hill AFB, Utah has been designated the lead repair agent and serves as the DMISA facility designated to repair the T-56 turboprop and any of its major components. Organic overhaul locations are operated and resourced by the U.S. Navy. Specifically, the 3 Naval Aviation Depots in North Island CA, Cherry Point NC, and Jacksonville FL are the Navy's organic aviation overhaul locations. Maritime organic repair sites are referred to as Ships Intermediate Maintenance Activities. There are approximately 40 Ships Intermediate Maintenance Activities located worldwide for the U.S. Navy. In 2004, there were 4726 commercial, 21 DMISA repair facilities and 43 organic [NAVICP, 2004b].

II.   RELATED STUDIES

While there are no previous studies of retrograde distribution networks, this section presents previous studies of distribution network design for RFI materiel.

A.   PREVIOUS STUDIES OF DISTRIBUTION NETWORKS

Ballou [1992] and Magae, Capacino and Rosenfield [1985] provide textbook discussion of strategic network planning to determine the number, location, product assignments and capacities of distribution centers or node types. In this section, we review several DoD strategic network studies related to DLA, NAVICP and general distribution network design.

1.   DLA Related

The DODMDS study following the Vietnam War analyzed the materiel, maintenance and storage distribution system of four military services within the continental U.S. This study excludes perishable subsistence, industrial plant equipment, ammunition, bulk petroleum, chemical, biological and radiological as well as major end use items [DODMDS, 1978]. The conclusions of the study suggest major savings upward a $100 million a year could be realized through the closures of nine depots and repositioning of certain categories of materiel closer to its customers [DODMDS, 1978]. Supporting this conclusion are extensive studies using two models of analysis. The first a mixed integer linear program was used to minimize depot and transportation costs. The other a simulation model that evaluates depot capacity and responsiveness to customers needs.

The Holmes study analyzes the DLA distribution network and proposes depot closure candidates in order to support a 1995 budget reduction [Holmes 1994]. In 1994, DLA operated 28 depots and supplied more than 45,000 customers with an excess of three million products procured from 10,000 suppliers. Holmes investigates 29 aggregate products, 113 aggregate customers and uses a commercial optimization-based decision support system, Strategic Analysis of Integrated Logistics System, for all his analysis.

Reich [1999] analyzes the DLA distribution network and proposes utilizing distribution points which are not collocated with Navy activities. Reich derives a simplified six node transportation scheme and aggregated customers for 57 depot level repairable items by using techniques suggested by the DODMDS and Holmes studies. The Reich study implies that, (a) a privately owned Premium Transportation Facility is more often the low-cost solution, (b) low weight items are not good candidates to store in a premium transportation facility; (c) and deleting DLA depots from the network barely affects the operating costs, while the associated customer wait time decreases significantly. Reich suggests that NAVICP should reposition more items into premium transportation facilities. [Reich 1999]

This study differs from the aforementioned studies in that it does not evaluate depot capacity nor the usage of a privately owned Premium Transportation Facility in determining optimal positioning of Navy Item Identification Numbers (NIINs). Additionally, there is no aggregation of end users or customers.

2.   NAVICP Related

Kaplan [2000] analyzes the Navy's wholesale inventory distribution network which operates within the DLA's distribution network and strategic positioning of Navy inventory with respect to meeting customer demands. Kaplan developed a heuristic algorithm that positions 35,521 line items to serve historical requisitions by Navy units over an 18-month period. The set includes 126 aggregated customers and 22 defense depots. The Kaplan [2000] study utilizes demand aggregation techniques suggested by the DODMDS and Holmes studies to reduce the scope of effort required to prepare demand-related data.

Kaplan's study shares much in common with the prior reviewed DLA studies. Its focus is on satisfying RFI customer demand not on the NRFI repair as we do in this study.

3.   Other Studies

Within the last 25 years, many studies have been conducted on distribution network design, including, Geoffrion [1976]; Magae, Capacino and Rosenfield [1985]; Geoffrion and Powers [1995]; Anderson Consulting [1994]. These studies propose a variety of models to reduce costs. As with Magae, Copacino and Rosenfield [1985 p. 307], Geoffrin and Powers [1995] suggest that these studies resolve the following basic distribution network questions:

- How many distribution centers should there be and where should they be located?

- What size should each distribution center be and what products should it carry?

- What distribution center (depot) should service each customer?

- Should all stocking points carry all products or specialize by product line?

- How should each plant's output be allocated among distribution plants or customers?

- For a given level of customer service, what is the cost savings for the proposed system?

This study does not investigate network distribution size nor the types of products carried. The study utilizes the DLA and NAVICP retrograde distribution network already in place and recommends shipping based on cost and time.

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III. OPTIMIZATION MODEL

This chapter presents a model (hereafter referred to as the "ILP") which evaluates DLR retrograde slated for repair based on a cost versus time tradeoff within a distribution network. The ILP determines transportation modes to use within the distribution network to reduce the overall costs of shipment prior to repair. The model does not assume capacity constraints for each item and there are no item interactions; therefore, each item is run independently.

For each NIIN, costs are minimized from end users through the network to DOPs subject to constraints on average shipping time (AveTime).

A. INTEGER LINEAR PROGRAM

Indices:

r   NIINS (r = 1, 2, 3,.....80,000 items)

i,j   Node (i or j = 310 shipfield unit, 14 atac nodes, 2 atac hubs, 25 defense depots, 3 designated overhaul points for each NIIN r);

m   Mode of shipment (m = FEDEX 1-day, FEDEX 5-day, FEDEX International 2-day, FEDEX International 5-day, AMC 7-day, DLA surface 7-day)

Sets:

A   Set of all arcs (i,j or j,i)

Data:

shipcost$_{r,i,j,m}$ Cost associated with shipping NIIN r from node i to node j using shipment mode m.

shiptime$_{r,i,j,m}$ Time associated with shipping NIIN r from node i to node j using shipment mode m.

b$_{r,i}$ Demand of NIIN r at node i.

avgtime$_r$ Maximum average permitted time of shipping NIIN r from a fleet unit to a DOP.

Nonnegative Variables:

X$_{r,i,j,m}$ Units of NIIN r shipped from node i to node j by shipment mode m for a specified NIIN.

Formulation: (For a given NIIN r)

$$\text{Minimize} \quad \sum_{(i,j)\in A,m} \text{shipcost}_{r,i,j,m} X_{r,i,j,m}$$

Subject to the following constraints:

$$\sum_{(j,i)\in A,m} X_{r,j,i,m} - \sum_{(i,j)\in A,m} X_{r,i,j,m} = b_{r,i} \qquad \forall i \qquad (1)$$

$$\sum_{(i,j)\in A,m} \text{Shiptime}_{r,i,j,m} X_{r,i,j,m} \leq \sum_{i:b_{r,i}>0} \text{avgtime}_r b_{r,i} \qquad (2)$$

$$X_{r,j,i,m} \geq 0 \qquad \forall (i,j) \in A,m \qquad (3)$$

B.   DESCRIPTION OF EQUATIONS

The objective function evaluates the shipping costs. Constraint (1) ensures conservation of flow at each node. Constraint (2) ensures a maximum average shipping time through the network. Because we are evaluating a time and cost tradeoff, this

constraint could have been stated as a separate objective function. We elected to state it as a constraint and vary the value of AveTime to obtain the tradeoff. Constraint (3) ensures nonnegative flow.

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IV. COMPUTATIONAL EXPERIENCE

A. DATA CHARACTERISTICS AND ASSUMPTIONS

This chapter introduces the data and discusses the steps to prepare the database for use in the ILP. The ILP is run on a Personal Computer with an Intel 2.0 GHz Processor and 1.00 Gigabyte of Random Access Memory. The General Algebraic Modeling System or GAMS [GAMS 2004] is used with an OSL solver [GAMS 2004] to solve ILP runs. Generation and solution times for ILP runs of individual NIINs are less than 2 minutes. The size of the model varies from NIIN to NIIN but is typically small consisting of about 50 constraints and 350 variables.

1. Database

This thesis uses a database consisting of 384,234 requisitions received from the NAVICP. Originally received in Microsoft Excel using Requisition File History from UICP, we import the date into Microsoft Access for data manipulation and analysis.

Characteristics of the database include the following:

- demand data from 01 June 2003 to 31 May 2004;

- NIIN shipping priority, weight and volume; and

- node location in relation to DOP.

Due to UICP program database constraints, NAVICP was unable to include locations in the database on the DOPs (node type 5). Therefore, we manually calculate all possible shipping route combinations from each node type 1-4 location to each node type 5 location.

2. Transportation Methods, Times and Costs

We determine methods of shipping of NRFI DLR NIINs based on location of the End Users, ATAC Nodes, ATAC Hubs and DDD. For example, a NRFI DLR item located at an end user (ships and squadrons) overseas in Japan (node type 1), would turn-in its DLR retrograde into an ATAC node agent (node type 2) also in Japan. Then the item would be flown to the ATAC hub (node type 3) in North Island, CA. Depending on

the DLA holding location of that item, it would either be sent using commercially contracted trucking (surface) or flown to the DLA location (node type 4) using commercial air Federal Express (FEDEX). Once at the DDD, the item is held in storage until it is inducted into repair at the overhaul point or DOP (node type 5). We find all possible shipping routes of a given NRFI DLR NIIN.

a.   Air Mobility Command (AMC)

The DoD utilizes cargo aircraft of the U.S. Air Force Air Mobility Command (AMC) to ship its medium to low priority repair parts and supplies from overseas locations to the U.S. and back. These channel flights provide the DoD the opportunity to move assets to and from its concentrated overseas locations and avoid commercial transportation costs. Shipping times associated with AMC service are 5 days or greater.

b.   FEDEX

Commercial shipping is generally viewed as the most expedient and reliable from of freight shipping. FEDEX, DHL and United Parcel Service are the primary means of domestic and international shipping for DoD units. They are part of the AMC World Wide Express (WWX) transportation website [AMC, 2005]. For this study, we use shipping rates from the FEDEX U.S. Government contract guide [FEDEX, 2004] for transportation costs of RFI DLRs from overseas and domestic locations to DOP locations.

c.   DLA Contract Ground Shipping

DLA ground shipping involves dedicated trucks that pickup and deliver RFI and NRFI parts to and from the DDD. Table 4.1 shows DLA ground shipping rates to and from DDD locations. Note how the shipper pays a higher price per mile for shorter distances and a lower price per mile for longer distances within a weight class.

		Distance (Miles)			
		<251	<651	<1501	<3001
	<499	$0.20	$0.16	$0.13	$0.12
Weight (LBS)	<999	$0.30	$0.24	$0.20	$0.17
	<1999	$0.45	$0.36	$0.31	$0.27
	<4999	$0.62	$0.50	$0.42	$0.37

Table 4.1: DLA shipping rate tables for 2004.
DLA shipping rates per mile are based on distance to ship and weight (lbs). Greater distances experience lower costs per mile within a particular weight class.

B.   DATABASE COMPLETION

Figure 4.1 is a snapshot of the database received in MS Excel format. Each month is identified in Microsoft Excel at the bottom. In total, more than 380,000 transactions are provided by NAVICP.

Figure 4.1: Snapshot of raw data from database received from NAVICP.

The database includes data fields as DLR shipping document ID, NIIN, End User, ATAC Node, ATAC Hub, DLA activity for storage as well as shipping dates and additional Transportation Control Numbers (TCN). Node Type 5 is not included in the data.

The www.onetouch.navy.mil (ONETOUCH) website produces technically screened background information on NIINs. Utilizing the www.iso-parts.com/CAGE website enables us to cross reference the NIIN to the source for commercial manufacturer and repair. Data from the ONETOUCH website and the NAVICP MRIL identifies the DMISA and organic repair sites used in repair. Because the NAVICP did not include NIIN information on node type 5 (repair actions) in the database, a reasonable location for repair or best guess is made. Figure 4.2 shows a snapshot of the database after being imported into Microsoft Access and populated with nomenclature and location names instead of NIINs and Uniform Identification Codes (UICs).

Figure 4.2: Snapshot data after conversion into MS Access.
The information is now more manageable by sorting the data by NIIN type and includes all 384,221 DLR shipping transactions in one database. Priorities, weights and volumes are included to facilitate shipping cost determinations from starting nodes to ending nodes.

The next step in developing a working network is to determine distances for all possible node-node combinations for node types 1 through 5. The www.airrouting.com website calculates ground and air distances with nautical and statue distances from both military and civilian air hubs. For example, air and ground travel between Dover AFB and DDD San Diego would be calculated using the airport locator function in www.airrouting.com. If shipping a retrograde item by commercial means using FEDEX, we calculate shipping rates for items weighing more the 150 pounds and determine destinations based on its representative zones [FEDEX, 2004] www.fedex.com/cgi-bin/regionlocator.cgi. At the receiving city, we use San Diego's Lindberg Field International Airport for FEDEX shipping. If shipping using government chartered air, we use the Naval Air Station North Island for military aircraft. If shipping retrograde by dedicated truck delivery or LTL (Less Than Truck Load) methods, we determine shipping rates based on distance and rate ranges for point to point mileage determination. Figure 4.3 shows the websites used to complete the database.
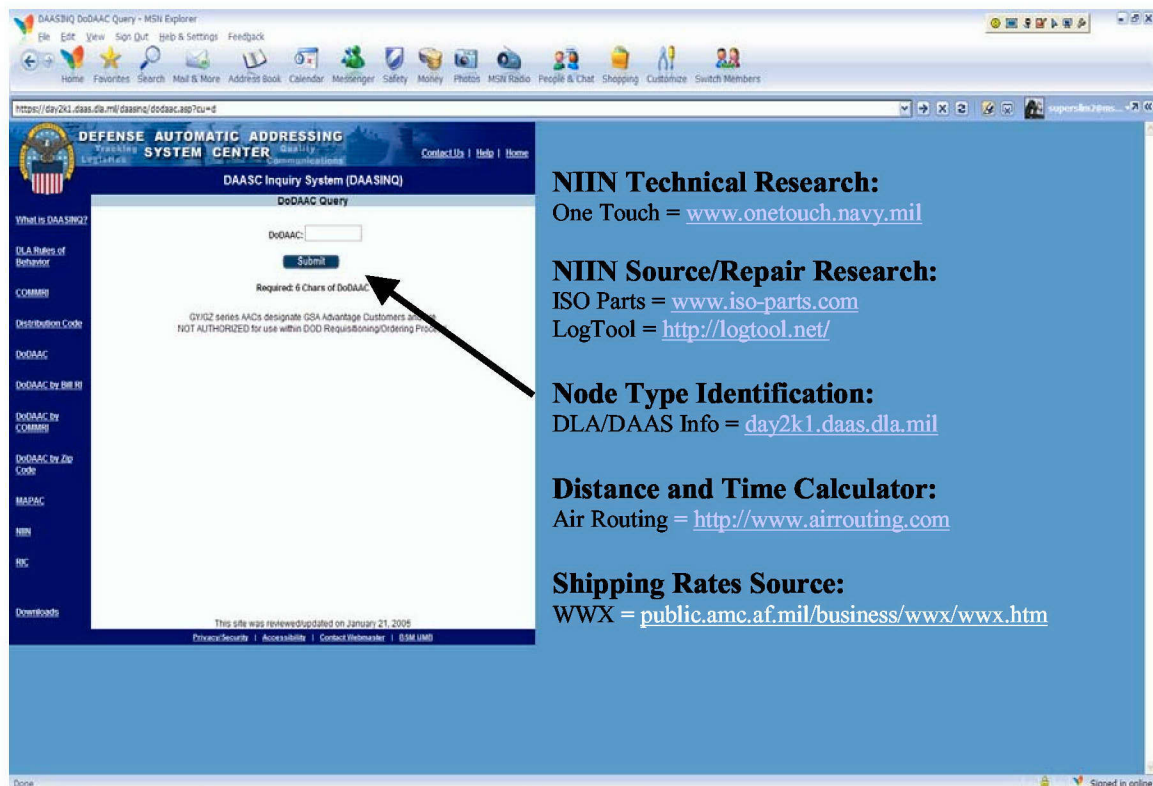
Figure 4.3: Websites used to find network data.

C.   REPRESENTATIVE ITEMS AND NETWORK CONSTRAINTS

Due to the need to manually obtain shipping costs for each node-node combination, we select a test set of six NIINs (3 aviation and 3 maritime). We choose items with various weights to capture representative shipping routes. We also utilize six modes of shipping. Items weighing 150lbs or less are considered packages. Items weighing 151 pounds or greater are consider freight. AMC, DLA and FEDEX charge different rate for freight and non-freight shipments.

Priority designators 01, 02, 03, 07 and 08 we equate to FEDEX (U.S. and international) high priority shipping in 1 to 2 days ship time. Priority designators 04, 05, 06, 09 and 10 we equate to FEDEX (U.S. and international) medium priority in 3 to 4 days ship time. Priority designators 11, 12, 13, 14 and 15 we designate with Government shipping low priority in 5 days or greater ship time. See Table 4.2 below listing priorities of shipping [NAVSUP, 1992].

Urgency of Need Designator	I	Force Activity Designator			
		II	III	IV	V
		Priority Designator			
A UNABLE TO PERFORM	01	02	03	07	08
B PERFORMANCE IMPAIRED	04	05	06	09	10
C ROUTINE	11	12	13	14	15

Table 4.2:   Table relating Force Activity Designators, Urgency of Need Designators and Priority Designators for shipping.

We use six modes of shipping based on three priorities, low, medium and high; we also separate the modes into two types, Commercial and Government. Commercial is

listed as medium and high priority or 3-4 days and 1-2 days respectively. Government is listed as low priority or 5 days or greater. We utilize FEDEX for commercial service, AMC for low priority international government air and DLA contracted trucking for surface shipping U.S. through government channels.

Table 4.3 shows NIIN 013-69-2118, the T56 Nozzle Assembly, network drawn from the database. The T-56 Turbo Prop Engine is flown on the P-3 Orion and C130 Hercules Aircraft. The U.S. Navy and NATO countries fly the P-3 Orion as a submarine hunter aircraft. The USMC, USAF and USN fly the C-130 assets as a cargo and troop transportation aircraft. The NIIN experiences a demand of 1,453 units during the 12 months.

T56 TURBO PROP NOZZLE ASSEMBLY		NIIN: 013-69-2118		STD PRICE $2152.00		WEIGHT (LBS) 177		http://www.airrouting.com/scripts/td calc.asp	
NUM	END USER	NUM	ATAC NODE	NUM	ATAC HUB	NUM	DLA STORAGE	NUM	DOP
E1	JRB WILLOW GROVE PA								
E2	NAS JACKSONVILLE FL								
E3	NAS PAX RIVER MD	A1	ATAC NODE JACKSONVILLE FL						
E4	NAS BRUNSWICK ME	A2	ATAC NODE PUGET SOUND WA						
E5	NAS WHIDBEY IS WA	A3	ATAC NODE SIGONELLA IT			D1	DDD OAKLAHOMA CITY OK		
E6	NAS SIGONELLA IT	A4	ATAC NODE PENSACOLA FL	H1	ATAC HUB NORFOLK VA	D2	DRMO SAGAMI JP	R1	DMISA TINKER AFB OK
E7	NAS POINT MUGU CA	A5	ATAC NODE PEARL HARBOR HI	H2	ATAC HUB SAN DIEGO CA	D3	DRMO NORFOLK VA	R2	NADEP NORTH ISLAND CA
E8	NAS NORFOLK VA	A6	ATAC NODE OKINAWA JP			D4	DRMO SAN DIEGO CA	R3	ROLLS ROYCE INDIANAPOLIS IN
E9	MALS 11 SAN DIEGO CA	A7	ATAC NODE CHERRY POINT NC						
E10	MALS 36 OKINAWA JP	A8	ATAC NODE YOKOTA JP						
E11	MALS 24 KANEOHE BAY HI								
E12	MALS 14 CHERRY POINT NC								
E13	JRB NEW ORLEANS LA								
E14	MCAS MISAWA JP								
E15	JRB FORT WORTH TX								

Table 4.3 The T56 Engine nozzle assembly redistribution network.

Nodes E1 through E15 represent the end users in the fleet. Nodes A1 through A8 represent ATAC nodes for retrograde turn in. Nodes H1 and H2 are the ATAC hubs in Norfolk VA and San Diego CA. Nodes D1 to D4 represent DLA locations for storage of retrograde prior to induction into repair. Nodes R1 to R3 represent a commercial, organic and joint military location for repair.

D.   RESULTS

It takes at least two days to get an item to a repair facility from an overseas end user. So, all results listed below use a minimum of two days.

T-56 Engine Nozzle Assembly:

The T-56 has an annual demand of 1,453 units. Figure 4.4 shows optimal shipping costs when AveTime is constrained from 2 to 8 days. 2-day shipping for the T-56 Nozzle Assembly is possible using mode 3 (FEDEX U.S. 1-day shipping) and mode 5 (FEDEX International 1-2 day shipping).
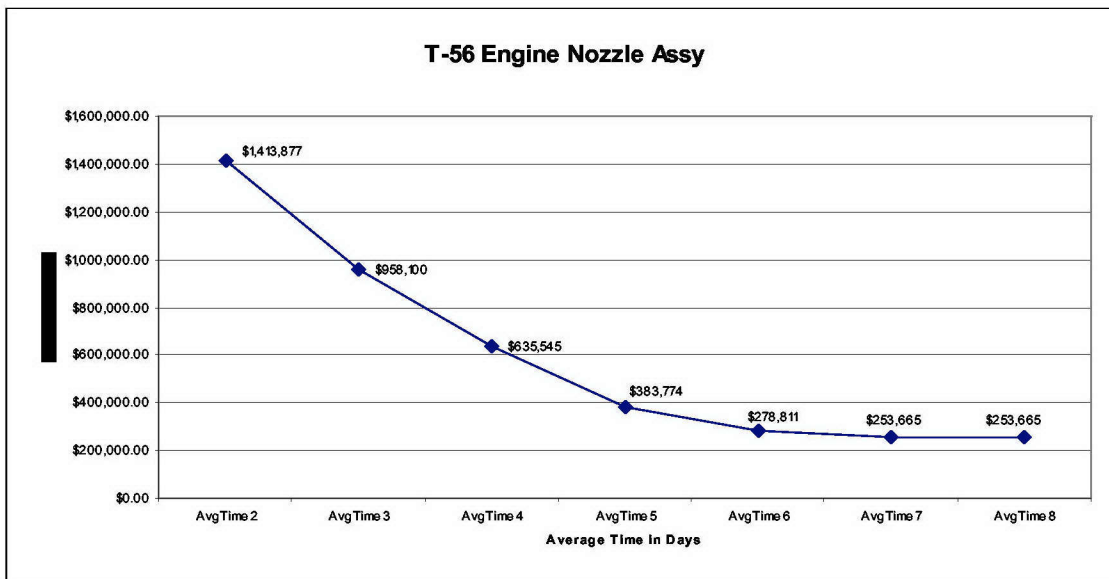
Figure 4.4: AvgTime shipping costs of a T56 Nozzle Assembly through network.

Shipping the T-56 Nozzle Assembly through the network with an AveTime of 2 through 8 days produces a variety of recommended shipping routes. The cost when AveTime is restricted to be no more than 2-days is found to be six times the cost when AveTime is allowed to be seven days or more. When AveTime can be no more than 5 days, it costs four times less than that of 2-day shipping.

26

When demanding 2-day AveTime, only direct shipment from end users to DOPs using high priority mode of shipping is possible. When AveTime equals 6 and 7 days, the ILP recommends shipping to all ATAC nodes and hubs using five of the six shipping methods. When having higher AveTime, we find that the lower cost AMC is used in place of FEDEX international economy (low priority). In all cases (AveTime of 2 through 8 days), the ILP does not recommend shipping the T-56 Nozzle Assembly to any of the DLA locations for storage due to the additional time and transportation costs.

Helo Fuel Pressure Indicator Valve:

The Helo Fuel Pressure Valve has an annual demand of 14 units. Shipping the Helo Fuel Pressure Indicator Valve through the network with an AveTime of 2 through 8 days produces a variety of recommended shipping routes. Figure 4.5 shows optimal shipping costs of AveTime of 2 through 8 days. The cost when AveTime is restricted to be no more than 2-days is found to be four times the cost when AveTime is allowed to be seven days or more. When AveTime can be no more than 5 days, it costs two times less than that of 2-day shipping.

As we found with the T-56, only direct shipment from end users to DOPs using high priority mode of shipping is possible when requiring 2-day AveTime. When AveTime equals 6 and 7 days, the ILP recommends shipping to all ATAC nodes and hubs using four of the six shipping methods. When having higher AveTime, we find that the lower cost AMC is used in place of FEDEX international economy (low priority). We again find, the ILP does not recommend shipping to any of the DLA locations.

Helo Pressure Indicator Valve
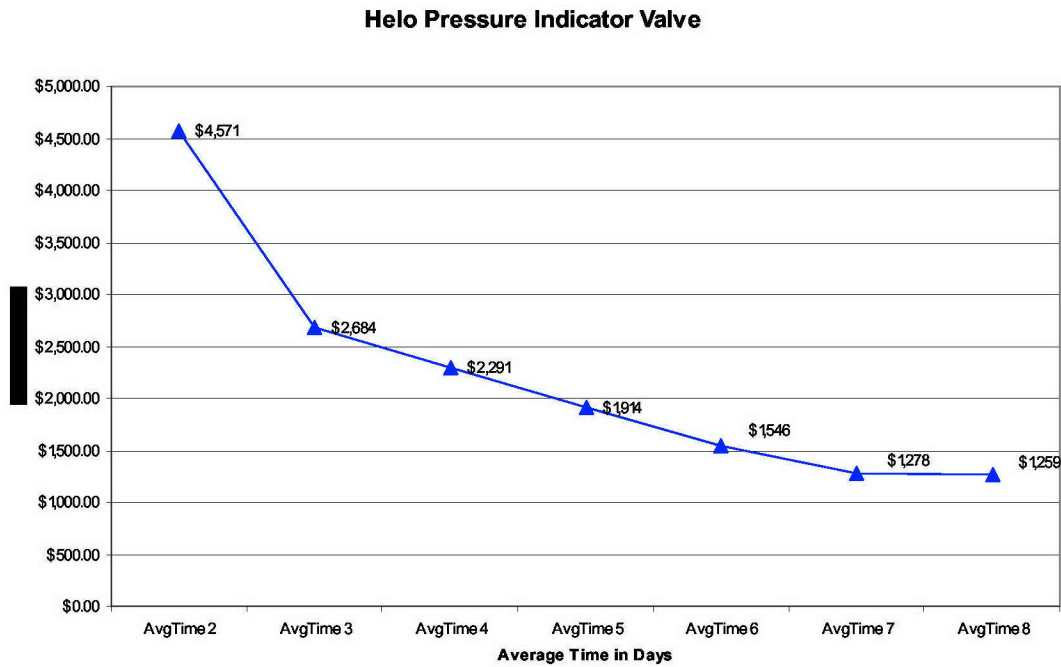
Figure 4.5: AvgTime shipping costs of a Helo Pressure Indicator through network.

Electronic Warfare Housing Assembly:

The Electronic Warfare Housing Assembly has an annual demand of 97 units. Shipping the Electronic Warfare Housing Assembly through the network with an AveTime of 2 through 8 days produces a variety of recommended shipping routes. Figure 4.6 shows optimal shipping costs of AveTime of 2 through 8 days. The cost when AveTime is restricted to be no more than 2-days is found to be 32 times the cost when AveTime is allowed to be seven days or more. When AveTime can be no more than 5 days, it costs 19 times less than that of 2-day shipping.

As we found with the T-56, only direct shipment from end users to DOPs using high priority mode of shipping is possible when requiring 2-day AveTime. When AveTime equals 6 and 7 days, the ILP recommends shipping to all ATAC nodes and hubs using five of the six shipping methods. When having higher AveTime, we find that the lower cost AMC is used in place of FEDEX international economy (low priority). We again find, the ILP does not recommend shipping to any of the DLA locations.

28

Electronic Warfare Housing Assemly

Figure 4.6: AvgTime shipping costs of an EW Housing Assembly through network.

Alternate Current Motor:

The Alternate Current (AC) Motor has an annual demand of 64 units. Shipping the Alternate Current Motor through the network with an AveTime of 2 through 8 days produces a variety of recommended shipping routes. Figure 4.7 shows optimal shipping costs of AveTime of 2 through 8 days. The cost when AveTime is restricted to be no more than 2-days is found to be nine times the cost when AveTime is allowed to be seven days or more. When AveTime can be no more than 4 days, it costs two times less than that of 2-day shipping.

As we found with the T-56, only direct shipment from end users to DOPs using high priority mode of shipping is possible when requiring 2-day AveTime. When AveTime equals 7 days, the ILP recommends shipping to all ATAC nodes and hubs using all six shipping methods. When having higher AveTime, we find that the lower cost AMC is used in place of FEDEX international economy (low priority). We again find, the ILP does not recommend shipping to any of the DLA locations.
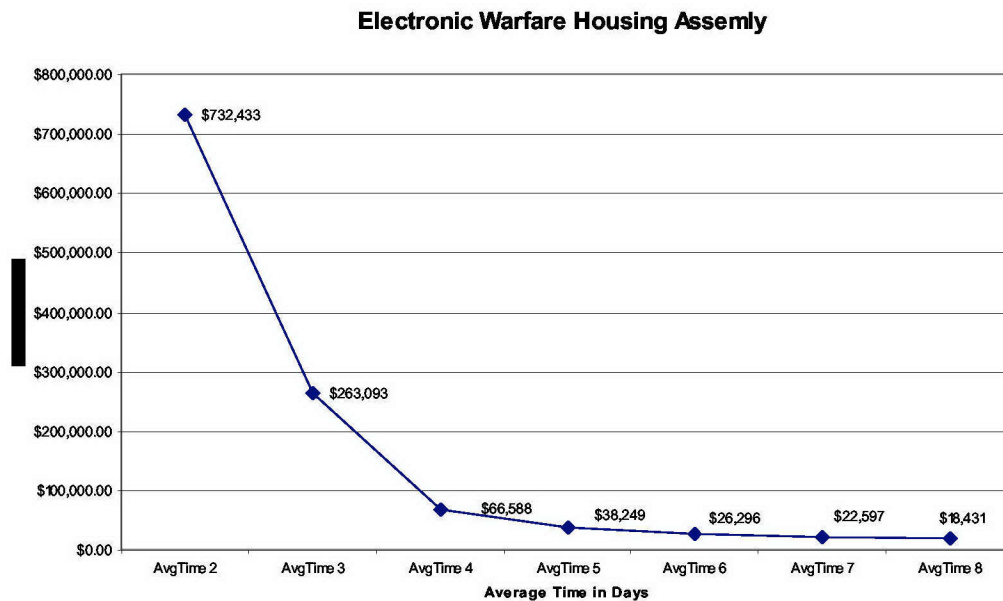
AC Motor

Figure 4.7: AvgTime shipping costs of an AC Motor through network.

Fire Control Circuit Card Assembly:

The Fire Control Circuit Card Assembly has an annual demand of 274 units. Figure 4.8 shows optimal shipping costs of AveTime of 2 through 8 days. The cost when AveTime is restricted to be no more than 2-days is found to be 53 times the cost when AveTime is allowed to be seven days or more. When AveTime can be no more than 5 days, it costs 13 times less than that of 2-day shipping.

As we found with the T-56, only direct shipment from end users to DOPs using high priority mode of shipping is possible when requiring 2-day AveTime. When AveTime equals 6 and 7 days, the ILP recommends shipping to all ATAC nodes and hubs using five of the six shipping methods. When having higher AveTime, we find that the lower cost AMC is used in place of FEDEX international economy (low priority). We again find, the ILP does not recommend shipping to any of the DLA locations.
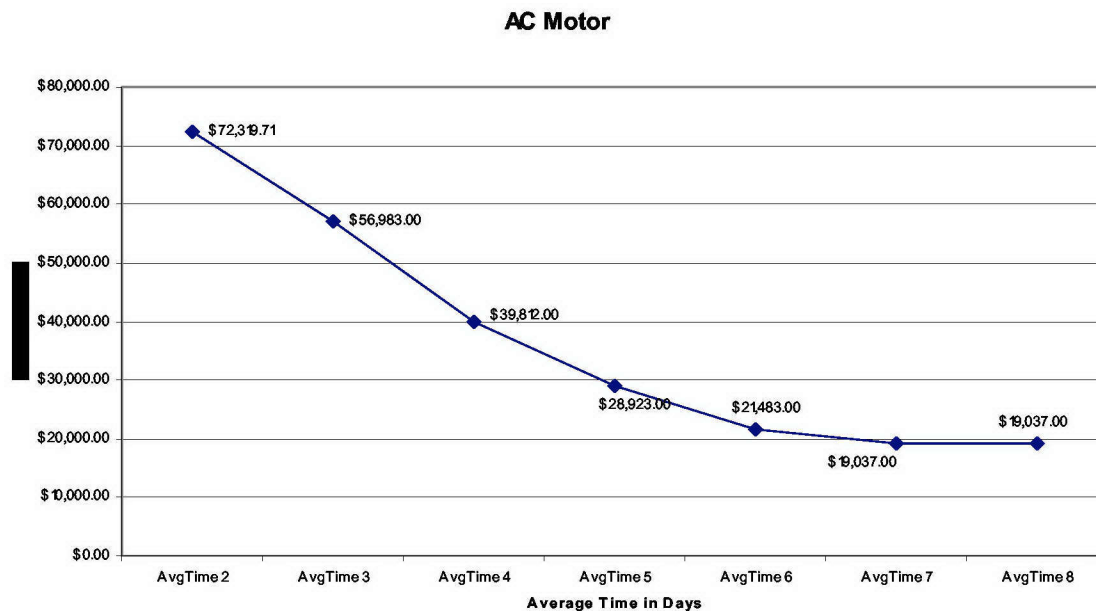
Circuit Card Assembly

Figure 4.8: AvgTime shipping costs of a Circuit Card Assembly through network.

Radio Communications Antenna:

The Radio Communications Antenna has a demand of 83 units. Figure 4.9 shows optimal shipping costs of AveTime of 2 through 8 days. The cost when AveTime is restricted to be no more than 2-days is found to be ten times the cost when AveTime is allowed to be seven days or more. When AveTime can be no more than 5 days, it costs five times less than that of 2-day shipping.

As we found with the T-56, only direct shipment from end users to DOPs using high priority mode of shipping is possible when requiring 2-day AveTime. When AveTime equals 6 and 7 days, the ILP recommends shipping to all ATAC nodes and hubs using five of the six shipping methods. When having higher AveTime, we find that the lower cost AMC is used in place of FEDEX international economy (low priority). We again find, the ILP does not recommend shipping to any of the DLA locations.
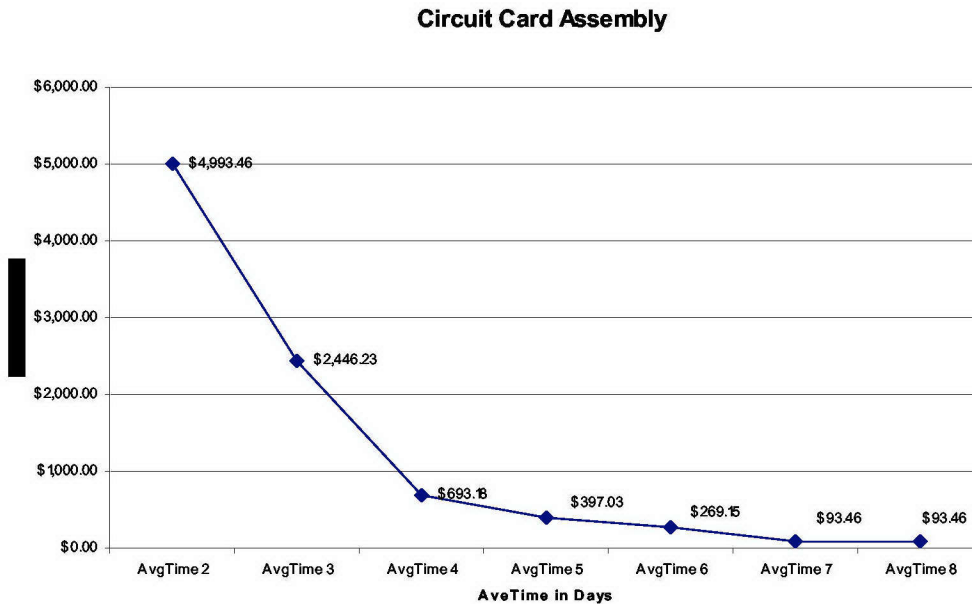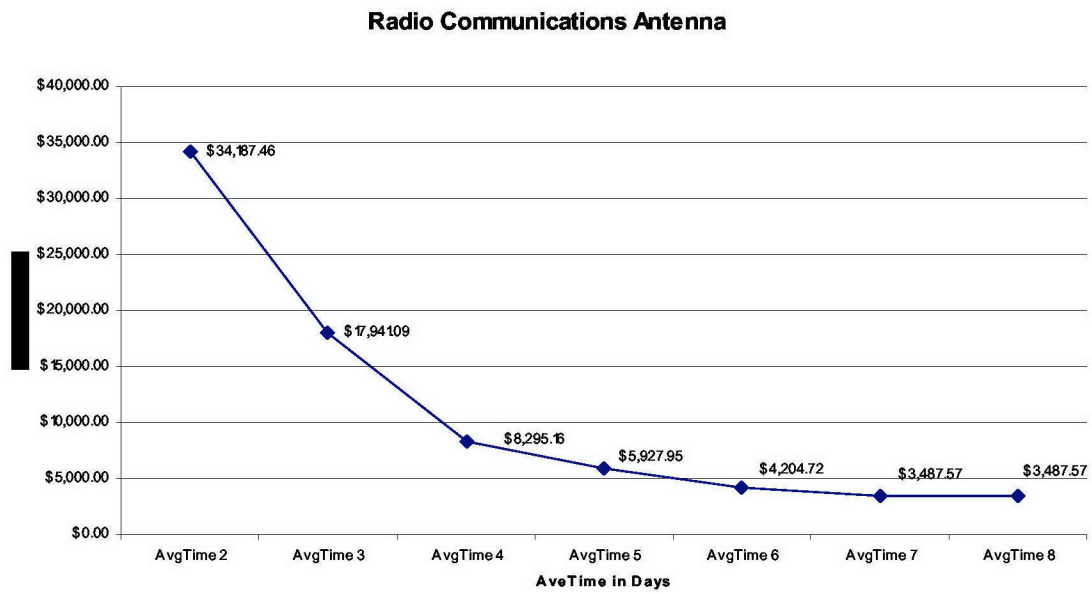
Radio Communications Antenna

Figure 4.9: AvgTime shipping costs of a Communications Antenna through network.

V. CONCLUSIONS AND RECOMMENDATIONS

This thesis models the NAVICP shipping of unserviceable but repairable (retrograde) Navy materiel or Depot Level Repairables (DLRs). It develops an integer linear program to prescribe minimum cost shipment recommendations of DLRs from fleet to repair locations within the NAVICP and Defense Logistics Agency (DLA) distribution system subject to constraints on average shipping time (AveTime NAVICP provided data on DLR shipments for one year from which we construct six representative DLRs, 3 of aviation and 3 of maritime cognizance. The analysis shows:

a. When constraining AveTime, we find that on average, 2-day shipping is 18 times that of 7-day and 8-day AveTime shipping. Likewise, 2-day shipping resulted in costs that were twice that of 3-day shipping and 5 times to 11 times that of the costs of 4 through 6 day shipping respectively.

b. The ILP recommends shipping through ATAC Nodes and Hubs and the use of different shipping modes for AveTime of 5 days or greater.

c. Shipping through DLA storage locations is not recommended for any of the scenarios.

Due to the limited nature of this study and the lack readily available data, we manually calculate shipping costs from FEDEX, AMC and DLA shipping charts. This data provides relative relationships between shipping costs between nodes in the network. Therefore we recommend that NAVICP and DLA identify and utilize exact shipping costs.

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